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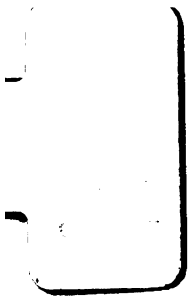

G. R. Baldwin
From W. E. Worthen
Feb'y 1863

BROOKLYN WATER WORKS.

REPORTS

ON THE

PUMPING ENGINES:

PROSPECT HILL, No. 1.
RIDGEWOOD, No. 2.

1861-'62.

BROOKLYN WATER WORKS.

REPORTS

ON

TRIALS OF DUTY AND CAPACITY

OF

THE PUMPING ENGINES

NO. 2, AT RIDGEWOOD,

AND OF

NO. 1, AT PROSPECT HILL,

MADE IN 1861-'2.

NEW YORK:
JOHN F. TROW, 50 GREENE STREET.
1862.

Eng 1102.62

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James R. Baldwin

REPORTS.

Report of Messrs. Smith, Groff, and Worthen on the second Brooklyn Pumping Engine at Ridgewood.

JAS. P. KIRKWOOD, Esq.,

Chief Engineer, Brooklyn Water Works.

DEAR SIR: Agreeably to the request in your communication of the 21st instant, and in conformity with the agreement between the parties thereto annexed, we have made an experimental test of the working qualities of the second Ridgewood Engine only, the Prospect Hill Engine being not yet in condition for trial. The results are as follows:

The test for duty, continued during 24 hours, gave for the combustion of 1 lb. of coal an effect of 589,854 lbs. ft., or 10,146 lbs. ft. less than that required by the contract.

The test for capacity, continued during 16 hours, gave, as measured in the

Reservoir, . . .	10,403,414 galls.
By Weir, . .	10,275,164 "

thus complying with the contract, whatever measures be adopted.

The experiments were conducted, on the 23d and 24th insts., upon the same general principles as on the No. 1 Engine; except that, on account of the fulness of the reservoir, and shortness of time, the experiments on duty and capacity were not entirely distinct, but some 8 hours' work has been used in common with both tests; and the

principle of continuous firing has been adopted, instead of drawing the fire as before.

In regard to the character of the workmanship of the machine, and the material of its construction, on the whole, both are extremely satisfactory; there are some minor details which are deficient, and which should have been attended to previous to the trial, but which may be easily perfected at a very moderate outlay. The engine has been used but 9 or 10 days, and is subject to all the disadvantages of new work; we are confident that, after having been used a longer time, and with slight modifications, it will easily come up to the required test of duty, and as a working machine prove itself superior in every respect to the first engine.

FREDERICK GRAFF,
W. E. WORTHEN,
ERASTUS W. SMITH.

October, 1861.

NOTES ON THE TRIAL OF RIDGEWOOD ENGINE No. 2, *Oct.* 23 *to* 25, 1861.

The steam pressure in the boilers ranged from 14½ to 18 lbs.; the average pressure was about 15½ lbs.

Number of strokes of engine during 16 hours' trial for capacity, from 2 P. M. Oct. 24, to 6 A. M. Oct. 25, 10,232.

The water was measured in the Reservoir, from 9:15 P. M. Oct. 23, to 6 A. M. Oct. 25, and at the conclusion of the experiments the loss by leakage was gauged, and allowance made therefor. The quantity thus measured, as delivered into the Reservoir during the 16 hours, from 2 P. M. Oct 24, to 6 A. M. Oct. 25, was

1,331,637 cubic ft. or 10,403,414 galls., N. Y. standard, or, divided by the number of strokes,
130.144 cubic ft. per double stroke,
or 1016.25 galls. "

As a check upon this measure, a weir was made upon the platform over which the water was delivered into the Reservoir, and the capacity of the pump was estimated from the heights above the weir, taken every 5 minutes during 4 hours, from 2 to 6 P. M., Oct. 24.

Capacity of pumps, as measured by weir,
128.54 cub. ft. per double stroke,
or 1004.22 galls. "

Formula for weir discharges from Mr. Francis' hydraulic experiments:

$$Q = 3.33\ (l - \tfrac{2}{10}h)\ h^{\frac{3}{2}}$$

l = 7.25 ft. h by average 0.993.

Capacity of pump by measure and calculation for a stroke of 9.75 ft., 134 27 cubic ft. per double stroke,
or 1048.98 galls. " "

The Ridgewood Engine No. 2 not having complied with the contract requirement for duty, as by the report of the engineers, Messrs. Graff, Worthen, and Smith, another trial was deemed necessary, and it was resolved by the Board of Water Commissioners, that their engineer, Mr. Worthen, "be requested to make the second test of said engine, and also to test the engine at Prospect Hill Reservoir."

Time was given for the carrying out of some slight alterations that were found useful by the former trial, and a defect having been found in one of the expansion pipes, it was taken out and a new one was put in; and the second trial was commenced on Jan. 9, 1862. The general results of the test were given in a brief note to the chief engineer, Mr. Kirkwood, on the 16th, but the full report (as follows) was not communicated till Feb. 13.

Report of Mr. Worthen on the second Ridgewood Pumping Engine.

JAMES P. KIRKWOOD, Esq.

Dear Sir : In my previous communication (of the 16th ult.) with regard to the duty and capacity of Ridgewood Pumping Engine, No. 2, as tested by me on the 9th and 10th ult., the results were stated as follows :

606,613 lbs. ft. duty for every lb. of coal consumed.

10,554,102 gallons per 16 hours as the rate of discharge into the Reservoir during the 24 hours of trial.

These calculations were based on investigations conducted as in the previous experiments on the No. 1 Engine, with the exception, that the firing was continuous, and both duty and capacity were tested at the same time.

The load on the pump pistons was ascertained, by observations on the gauge attached permanently to the rising main, and placed beneath the vacuum and steam gauges of the cylinder ; to which is added the static pressure due to the height of the gauge above the average level of the water in the pump well. The boilers were fired up early on the morning of the 9th, and the engine was run intermittently till about 12 M., when everything was ready for trial ; the first coal was weighed 12 h. 30 m., and record was then taken of every shovelful of coal that was thrown on the grates, and upon what grates it was thrown. The coal was weighed in lots of ~~3,000~~ lbs. each; record was taken of the time when each lot was cleaned from the floor, and from the number of shovelfuls in each lot, the weight of

each shovelful is estimated and plotted on the profile hereto annexed.* The horizontal lines represent hours, a division of 10 to the hour, or 6 minutes to each small division; the perpendicular divisions represent the weight of coal, 100 lbs. to each small division. By observation of a profile thus constructed, it will be seen how much coal is consumed from hour to hour, and with what care the firing was conducted. During the whole experiment the fire, water, and steam, were kept as nearly constant as possible.

The firing was continued and coaling noted till after 4 o'clock P. M. on the 10th ult., but the time selected for the experiment has been the 24 hours, from 2 P. M. 9th, to 2 P. M. 10th; the quantity consumed has been taken from the profile. As in the experiments on No. 1, the quantity of coal in the ashes and cinder, during the whole firing, has been taken, and the percentage due to the quantity consumed during the test has been deducted. This, with a small deduction of coal, for an excess of $\frac{1}{2}$ inch of water in the boilers, at 2 P. M., 10th, over that at 2 P. M. on the 9th, has been taken as the net consumption on which the above calculation of duty has been based.

As in these last tests the responsibility for the accuracy of the experiments rested upon myself alone, and that the data obtained might be open to inspection of parties not present, in addition to observations of the gauge, cards were taken from indicators at the top of both pumps, in the positions *I*, *I'*, shown on PL. I., two at each place every hour; a few of the cards are annexed, but the average was taken for the whole 24 hours, 50 from each pump.

From the average thus taken the duty has been calcu-

* The profile accompanying the Report has not been printed, but its construction will be understood from the partial one now attached to the Report on the Prospect Hill Engine.

lated, as will be explained hereafter; and although it is somewhat above the duty as established by the gauge, and heretofore given, I think it is the more reliable and correct, as the data are of record, and not of observation, and contain the friction, not previously noted by the gauge, of the main beneath it.

The coal used was Buck Mountain, and the residue of fine coal which fell through the grates unconsumed, and was deducted in the previous calculation, has not been deducted in this, as this residue, although it might be useful for some purposes, will never be of enough account to screen for firing under these boilers.

Indicator cards were taken at each end of the steam cylinder every hour during the whole trial, and an average of them is given for the 24 hours of the trial for the purpose of comparing the steam load with that of the pumps, and the power absorbed in the working of the feed and air-pumps, the valve geer, and friction of the machinery.

The dimensions of the pumps were taken in the previous trial, and were found to be 36 inches in diameter.

The area is, therefore, . . .	1017.88	sq. in.
The pump piston rod, 8¼ diam., area, .	53.46	"
Net area of piston, . .	964.42	"

From observations on the 9th and 10th insts., during the 24 hours—

Average pressure at lower pump indicator, .	76.07	lbs.
" vacuum " " " . .	6.48	"
" pressure at upper pump indicator, upper stroke, ...	65.04	"
" pressure at upper pump indicator, down stroke, ...	67.01	"

Counter at 2 P. M. 9th inst. . .	96.697
" 2 " 10th inst. .	112.183
Number of double strokes during the 24 hours,	15,486
Average length of stroke, ...	9.74 feet.
Temperature of water in pump well, . .	42° Fahr.
" " hot well, . . .	70° "
Average pressure in boilers, ...	18 lbs.
" temperature in boilers by Pambour's tables, ...	257° Fahr.
Water in boilers at 2 P. M., 10th, $\frac{1}{2}$ inch higher than at 2 P. M., 9th inst., or by calculation water, ...	1,869 lbs.
Coals used to 2 P. M., 9th inst, by profile, .	2,420 "
" " 2 P. M., 10th inst., " . .	41,530 "
Coal used during the 24 hours of test, . .	39,110 "
Coal required to raise 1,869 lbs. of surplus water in the boilers from 70° to 257°, $\frac{1869}{53.4}$ =	35 "
Net coal used during the 24 hours' test, . .	39,075 "

WATER LOAD IN THE UP STROKE OF THE STEAM PISTON.

The water above the lower pump piston exerts a pressure on the piston equal to the sum of the pressure, as shown by the lower indicator, and of that due to the height of the indicator above the piston at its half stroke.

Beneath the piston we consider the vacuum to be that due to the height of the piston at half stroke above the average level of the water during the experiment. This is not strictly correct, as will be easily understood by looking at PL. I.; nor is the pressure above the piston at half stroke exactly that due to the average load, in consequence

of the height of the water in the well; the latter is a little in excess, whilst the allowance for the vacuum is a little too small; the errors very nearly balance, as we find by calculation.

As the lower pump piston is raised, the upper pump piston descends, and the upper piston rod acts as a pole plunger, and displaces water equal to its section multiplied by its stroke, under an average pressure equal to that due to the position of the piston at half stroke. This pressure is determined from the upper indicator, and the height of the indicator above the piston at its half stroke. Hence we estimate the pressure on the pump pistons in the up stroke of the engine, as follows:

Average pressure at lower indicator,		76.07 lbs.
Height of indicator above piston at half stroke—Plate I.—10 ft. pressure,	$\frac{10}{2.31} =$	4.33 "
		80.40 "
80.4 × 964.42, net area of piston pressure on top of lower pump piston,		77539.37 "
Height of lower pump piston at half stroke above average level of water during experiment,	2.12 ft.	
Vacuum due to this height,	$\frac{2.12}{2.31} =$ 0.92 lbs.	
0.92 lbs. × 1017.88, area of bottom of pump piston,		936.45 "
Total load on lower pump piston,		78475.82 "
Average pressure of upper indicator at down stroke of upper pump,	67.01 lbs.	
Height of indicator above piston at half stroke,	16.08 ft.	
Pressure due at this height,	$\frac{16.08}{2.31}$ 6.96 "	

Total pressure on piston at ½ stroke, 73.97 lbs.	
73.97 × 53.46, area of piston rod, . .	3954.43 lbs.
Total water load on up stroke of piston, .	82430.25 "

Water Load in the down Stroke of the Steam Piston.

The upper pump piston is raised, and the average pressure exerted on the upper surface of the piston is estimated as equal to the sum of the pressure, as shown on the upper indicator, and that due to the height of the indicator above the piston at half stroke. Beneath the piston the vacuum is estimated by the average vacuum, as shown on lower pump indicator, and the height of the piston at half stroke above this indicator. The lower pump piston rod in the down stroke of the engine, is partly drawn down by the vacuum, and partly forced beneath the level of the water in the pump well; calculation has been made of the relief due to the excess in the vacuum, but is now neglected as of too little amount.

Average pressure at upper indicator in up stroke of upper pump piston, ...		65.04 lbs.
Height of indicator above piston at half stroke, ...	16.08 lbs.	
Pressure due to this height, $\frac{16.08}{2.31}$ . . .		6.96 "
		72.00 "
72 × 964,42, net area of piston, . . .		69438.24 "
Average vacuum by lower indicator,	6.48 lbs.	
Height of upper pump piston at ½ stroke above indicator,	4.32 ft.	
Vacuum due to this height, $\frac{4.32}{2.31}$	1.87 "	
	8.35 "	

8.35×1017.88, area of bottom of piston, .	8499.30 lbs.
Total load on upper pump piston, .	77937.54 "
" " lower pump piston, .	78475.82 "
" " upper pump piston rod, .	3954.43 "
Total water load, .	160367.79 "

The total water load, multiplied by the length of stroke and by the number of strokes, and the product divided by the coal consumed during the strokes, will be the duty of the engine ; thus,

$$\frac{160367.79 \times 9.74 \times 15486}{89075} = 619.037 \text{ lbs. ft.}$$

for each pound of coal consumed during the experiment.

Capacity from Messrs. Graff, Smith and Worthen's Report on Experiments made 23d and 24th Oct., 1861 : 10,403,414 galls. discharged into the Reservoir in 16 consecutive hours.

In my previous communication, the test of capacity was estimated during the whole duration of the duty test, and referred to the required time of 16 hours ; but, during the first 16 hours, the average number of strokes and discharge of pump was somewhat larger than the subsequent 8 hours.

During the first 16 hours of the experiment there were pumped into the Reservoir, as there measured, 10,652,366 gallons.

For a number of hours consecutively, the average number of strokes per minute was very nearly 11, or at the rate of about 10,800,000 gallons per 16 hours.

Capacity of pumps per double stroke :

By calculation, 1047.5 gallons,
Reservoir measure, 1022.3 gallons.

By the average of the indicator cards, taken from both ends of the steam cylinder every hour during the 24 hours of the test, the pressure was found to be 15,475 lbs.

The diameter of the cylinder, as taken from Messrs. Woodruff & Beach's plans, was 85 in., or 5674.51 sq. in. area ; $15.475 \times 5674.51 = 87813$ lbs. average load on steam piston during each stroke.

The average load on the pump pistons is

$$\frac{160368}{2}, \text{ or } 80134 \text{ lbs.},$$

or a little less than 9 per cent. less load on the pumps than on the steam piston. No. 2 Engine is therefore fully equal to No. 1 in respect to the economy of working and friction of parts ; as, in addition to the work done by No. 1, the feed pump to the boilers is connected with No. 2, whilst the feed to the No. 1 boilers is independent of the engine, a Guild & Garrison pump being made use of for this purpose.

By calculation by volumes from the steam cards, the evaporation of the boilers was found to be about $8\frac{1}{4}$ lbs. of water per pound of coal ; a result very nearly equal to that found by Mr. Copeland and myself in our experiments on the Hartford pumping engine.

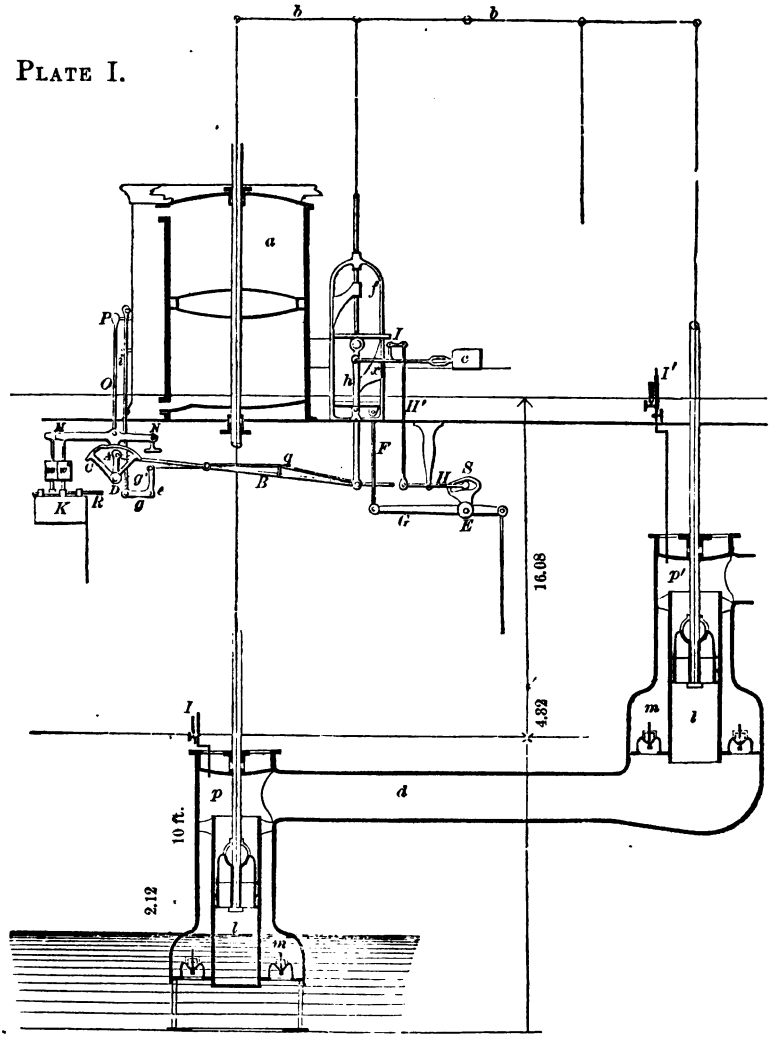
The usual guards, for accuracy in the experiments, have been made, by testing and comparing the indicators and scales ; and they were found to be in such condition as to require no correction in the data obtained.

The results deduced, I trust, will be found consistent with the data, and the method of the investigation satisfactory to yourself. Yours truly,

W. E. WORTHEN.

Feb. 13, 1862.

PLATE I.



DESCRIPTION OF RIDGEWOOD ENGINE, NO. 2, PLATE I.

In the Plate, *a* is the steam cylinder with piston, steam and exhaust ports, like other engines. In the bottom of steam cylinder is a stuffing box, through which the steam piston rod passes—and is coupled below to the rod of lower pump, *p*. *b* is the beam, to one end of which the piston rod is connected by a cross-head and links. The upper pump rod is connected to the other end of beam in the same manner as the steam piston rod. *f* is a frame moving with the beam in guides, which, in combination with the water cylinder, *c*, and roll levers, *h*, works the steam and exhaust valves. *e* is the lower rock shaft, which is connected to the upper or main rock shaft (hung in bearings between the side pipes) by the arms, *g*, *g'*, and rod, *i*. The lower rock shaft is operated from the lower ends of the roll levers, *h*. The piston of the water cylinder, *c*, is connected to the roll lever near its upper end. *C* is a segment, one part of the face being formed on a longer radius than the other (the difference being equal to the lift of the steam valves), and fastened at the centre to the rock shaft, *D*. This segment is adjustable by hand, and its office is to close the steam valves, early or late in the stroke, as may be required. The rock shaft, *D*, is connected through the arm, *A*, by the rod, *B*, to an arm on the rock shaft, *E*. This latter shaft is operated from the frame, *f*, by the rod *F*, and lever, *G*. The valves of the water cylinder, *c*, are operated from the rock shaft, *E*, by the Cam arm, *S*, and rods, *H* and *H'*, and right angled arm, *I*. The steam valves are operated by the cataract, *K*, which consists of two small open water cylinders (one for

each steam valve), fitted with pistons and weighted with the weights, *w*, *w'*. Each plunger rod is connected to one end of a lever, *M*, the other end, *N*, being the fulcrum; this lever is connected to the steam valve stems by the rod *O*, and arm, *P*. When the steam valve is closed, it is kept so by a latch bolt, *R*, inserted into a socket in its cataract plunger rod, the latch being moved into gear by a spring on the back of it, and withdrawn by an arm on the rock shaft, *e*.

Having described, as fully as the limits of this Report will permit, the various devices for operating the steam and exhaust valves, we will now endeavor to show their action taken as a whole, in the effective working of the engine.

Assuming the piston in the steam cylinder to be at half stroke (as shown in the Plate), and the lower steam valve being still open, the different parts of the gearing described above, and depending on the motion of the beam for theirs, will also be at half movement, but the cataract plunger attached to the lower steam valve will be at the bottom of its cylinder, and the latch, *R*, withdrawn. Now, when the piston has reached that part of the stroke when the lower steam valve ought to close, and the remainder of the stroke be performed by the expanding steam, the closing face of the segment, *C*, moves under the lever, *M*, by the operation of its connecting rod and arm—as before described—closing the lower steam valve instantly through the rods, *O* and *P*, at the same time carrying its cataract plunger to the top of its cylinder, being held there by the latch bolt. The piston continues moving upward until it has reached the point where the lower exhaust and upper steam valves should open: the former operation being performed by the inclined plane, *x*, on the inside of frame, *f*,

coming in contact with the roll on the upper end of the lever, *h*, moving it out of the perpendicular, at the same time giving a like movement in an opposite direction to the lower end of the lever, which opens—through the rod, *q*, and the lower and upper rock shafts—the lower exhaust valve.

The water cylinder, *c*, now comes into play, finishing the operation by carrying the roll lever to its extreme movement quickly, liberating by its action through the rod, *q*, and arm on rock shaft, *e*, the latch bolt of the upper steam valve cataract plunger, permitting the latter to fall open by the gravitation of its weighted plunger rod, and admitting steam on the upper side of the piston, checking it in its course, and forming a cushion ; the valve still being open, the movement of the piston is reversed, and the downward stroke commenced. When the piston has reached the point of "cutting off," the upper valve is instantly closed by the same operation as that described above for the lower steam valve.

PUMPS.

The lower pump, *P*, is placed in a well below the engine room floor, and directly under the steam cylinder ; the upper pump, *p'*, is also beneath the floor, and connected directly to the opposite end of beam. This pump has a nozzle, *n*, to which the forcing main is joined. Each pump is constructed of two barrels, *l* and *m* ; the inside one, *l*, being the working barrel, fitted with a bucket and double-beat valve, and the annular space between them being connected to the suction by eight double beat valves.

To the novel form of these pumps is due in a great measure the efficiency of the machine ; for by this combina-

tion of the two barrels there is presented to the moving column of water through the valves a net area much larger than that of the working barrel itself, thus allowing the velocity of the column to conform to that of the moving bucket, and in this way reducing the friction to a minimum.

Their operation is as simple as it is effective, and is described in a very few words, as follows:

The lower pump on its up stroke lifts the water above its bucket through the connecting pipe, *d*, and through the annular valves and valve of descending bucket of upper pump, at the same time charging itself below its bucket by suction. On its down stroke, the upper pump is lifting the charge above its bucket, and filling the space below it by suction; the lower pump again ascends, performing the above operation, each pump moving on its up stroke a column of water about 36 inches in diameter, 10 feet toward the Reservoir.

BOILERS.

The boilers are three in number and of the return drop flue variety:

Length of boiler,	30 feet.
Diameter,	8 "

Two fire boxes to each boiler:

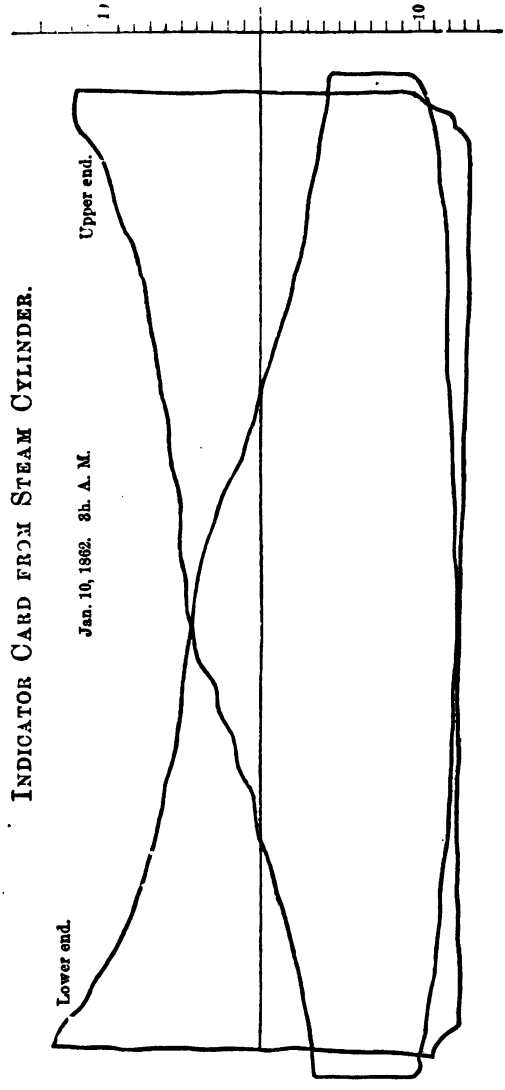
Length of grate,	6 ft. 8 inches.
Width of each grate,	3 ft.

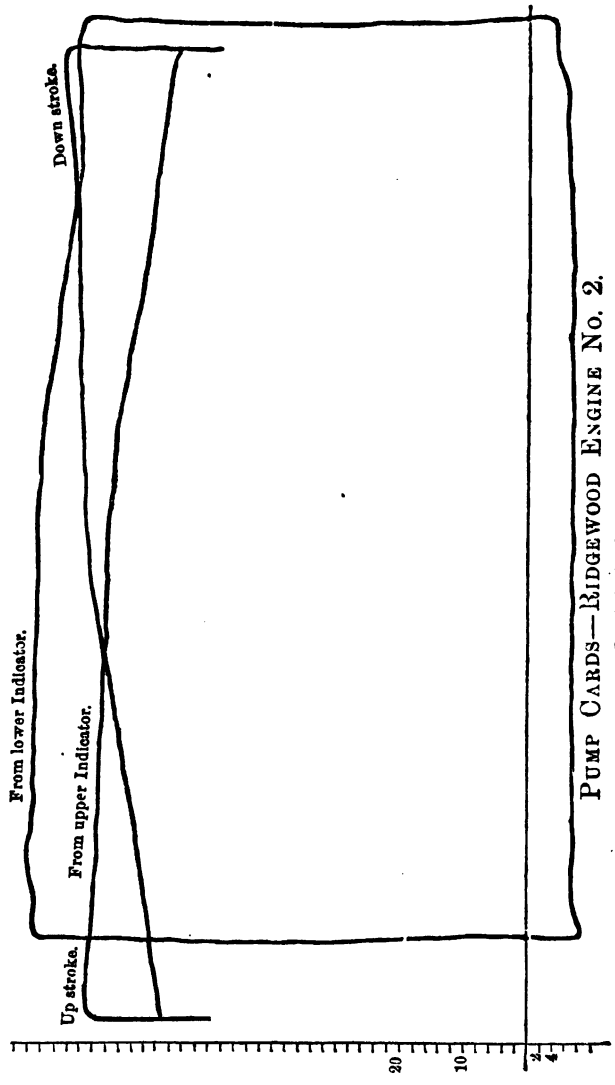
Four upper flues to each fire box:

Length of upper flues,	21 ft. 6 inches.
Diameter,	19 "

Sixteen lower flues to each boiler:

Length of lower flues,	18 ft. 6 inches.
Diameter,	8½ "


INDICATOR CARD FROM STEAM CYLINDER.
Jan. 10, 1862. 8h. A. M.
Upper end.
Lower end.



PUMP CARDS—RIDGEWOOD ENGINE No. 2.
Jan. 9, 1862. Midnight.

EXPLANATION OF PUMP INDICATOR CARDS.

The indicator *I* on lower pump gives a complete card, but in determining the load on the lower pump piston, the pressure above the piston is taken from the upper line of card (76.07 lbs.), to which is added the pressure due to the height of the indicator (10 feet) above the piston at half-stroke, and the vacuum below the piston is taken from the height (2.12 feet) of the piston at half-stroke above the average level of the water in the well during the experiment.

The indicator *I'* from the upper pump gives a card in which two lines of pressure are represented ; that from the right to left is due to the up stroke of the lower pump ; that from the left to the right is due to the up stroke of the upper pump, and is used (65.04 lbs.) in making up the load on the upper pump piston, to which is added the pressure due to height (16.08 feet) of the indicator above the piston at half-stroke, the vacuum below the piston is taken from the vacuum (6.48 lbs.) as shown on the card from the lower indicator, to which is added the vacuum due to the height (4.32 feet) of the upper pump piston at half-stroke above the indicator *I*.

Report of Mr. Worthen on the Pumping Engine at Prospect Hill.

JAMES P. KIRKWOOD, ESQ.,
Chief Engineer Brooklyn Water Works.

Dear Sir : Having made a series of experiments, to test the capacity and duty of the pumping engine at Prospect Hill, I respectfully submit the following report of the manner of conducting the experiments, the method of calculating, and the results obtained.

The pumps were ready for operation, and were started, for the first time, on the 5th ult. So long time had already been consumed in the construction of the machine, and so important was it to have the trial and report as soon as possible, that it was decided to go on with the test without any preliminary running of the engine. A week was consumed in putting on the small pump which returns the injection water to the rising main, and arranging some small matters for the placing of the indicators, and on Tuesday, the 13th ult., the trial was commenced. Up to this date, the pumps had not been run, in the aggregate, 20 hours, and no data had, or could have been obtained, of the best circumstances, as to pressure of steam and speed, from which to obtain the required duty ; I therefore decided to run the engine during the balance of the week, varying the pressure of steam, the velocity of the engine, and the pressure upon the induction side of the pumps. The results have been tabulated, and may be of use for future reference.

The experiments were continued until 9 A. M. of the 17th ult., when, having filled the Reservoir to the height of nearly one foot above that ever contemplated, and finding that the engine had already complied with the requirements of the contract, the fires were drawn.

The methods of firing and of noting the coal consumed were similar to that adopted in the experiments on Ridgewood Engine No. 2. The boilers were fired up early on the morning of the 13th ult., but the experiments were not commenced till noon; the counter of the engine was then taken, the height of water in the Reservoir, and the quantity of coal, as soon as it was required. The coal was weighed in lots of 100 lbs. each; record was taken of the time of each firing, and the quantity used; a profile was then made, on cross-section sheets, the horizontal lines representing the times, and the perpendicular lines the quantity of coal. And from the profile can be readily seen the quantity of coal consumed from hour to hour.

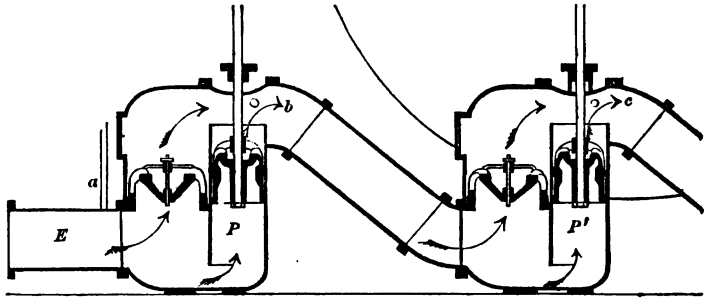
As in all previous experiments, the quantity of unconsumed coal in the ashes and clinkers has been deducted from the quantity of coal fired; the same allowance has been made in these experiments, but the deduction is so small, that were it omitted, the engine would still far exceed its requirements.

The quantity of water discharged into the Reservoir is deduced from heights taken in the glass tube in the Gate-House, and from tables of capacity furnished by Mr. Lane.

The work done at the pumps is calculated from the average pressures from indicator cards taken every half hour; from the number of revolutions, as shown by the engine counter; and from the measured length of stroke

and diameter of the pumps ; to which is added the lbs. ft. of work done at the small plunger pump, discharging the injection water into the rising main. No account is taken of the work done in supplying the boiler feed.

The accompanying figure illustrates the points from which pressure cards were taken. The indicator, by means of cocks, could be connected with either of the points *a*, *b*, or *c*. When in connection with *a*, the connections with the other points being shut off, the line shown on the indicator was the pressure with which the water was forced into the 1st pump *P* ; when in connection with *b* only, two lines are



shown on the card, the upper being the pressure of the water as it is lifted by the bucket of the 1st pump, the lower line the pressure of the water as it is forced into the 2d pump *P'*, whilst it makes its up-stroke. When in connection with *c* only, the indicator gives nearly a single line upon its card, the pressure on the rising main at this point.

The load at the 1st pump is estimated by ordinates on the cards between the lines, as given from *a*, for the lower line, and the upper line as taken at *b* ; whilst the load of the 2d pump is estimated from ordinates between the lower line taken from *b*, and the line from *c*, for the upper line. The lines are marked in light and heavy line on the ac-

companying cards. From these cards thus taken every half hour, and pressures averaged, a profile has also been plotted, and from this profile the average pressure on the pumps from hour to hour has been estimated, measured, and tabulated, to supply the data for calculation.

The dimensions of the pumps were found to be as follows :—

Diameter of lower pump,	20.3125	inches
" upper "	20.1875	"
or an average of	20.25	"
Stroke of lower pump,	3.4685	feet
" upper "	3.4633	"
Average taken at	3.466	"

Pump returning injection to the main :—

Diameter of plunger,	8.0	inches
Stroke,	1.604	feet

Diameter of piston rod of large pumps, 3 inches, which is to be taken from the area of the lower pump, but acts as a plunger pole in the down-stroke of the upper pump.

Area of both pumps,	644.126	sq. in.
Less piston rod,	7.069	"
Net area,	637.057	"
Area of return pump,	50.265	"

It was my intention to have selected as the test of duty, the 24 consecutive hours which gave the highest result ; but after making my calculations, I thought it would be most satisfactory if the result of the whole trial were given, and the maximum of 10 hours' trial, near the last of the experiments.

Coal fired during the experiments, from May 13th, at noon, to May 17th, at 9 A. M., 93 consecutive hours, ...	14,180 lbs.
Add for difference of level of the water in the boiler at beginning and at end of trial,	40 "
	14,220 "
Less coal in ashes, ...	383 "
Coal consumed, ...	13,837 "
Average pressure from pump cards, . .	29.96 "
" " plunger pump, . .	40.
No. of strokes, ...	129,557
$637.057 \times 3.466 \times 29.96 \times 129,557 \div 13,837 =$	619,381
$50.265 \times 1.604 \times 40. \times 129,557 \div 13,837 =$	30,196
Duty of 1 lb. of coal, . . .	649,577 lbs. ft.

The requirement of the contract was 600,000 lbs. ft. The engine therefore exceeds her requirements, on a test, never contemplated in the contract, of 93 hours instead of 24 hours.

The duty estimated in a similar manner for 10 hours, from 7 P. M., May 16th, to 5 A. M., May 17th, was found to be	684,042 lbs. ft.
The capacity, as guaged in the reservoir, for the time required by contract, 16 hours, from 12 P.M., 13th, to 4 P. M., 14th ult., was found to be	3,068,304 gallons
Requirement of contract, . . .	2,500,000 "
The capacity of pumps, as guaged at the reservoir, for 78 hours, from	

noon, May 13th, to 6 P. M., May
16th, was found to be . . 112,036 gallons
no allowance being made for leakage.
The number of strokes during the 93
hours, or whole trial, was . . 129,557
129,557 × 112,036 = 14,557,027 gallons
for 93 hours, or at the rate of

for 1 hour, 156.557 gallons
for 16 hours, 2,504,435 "

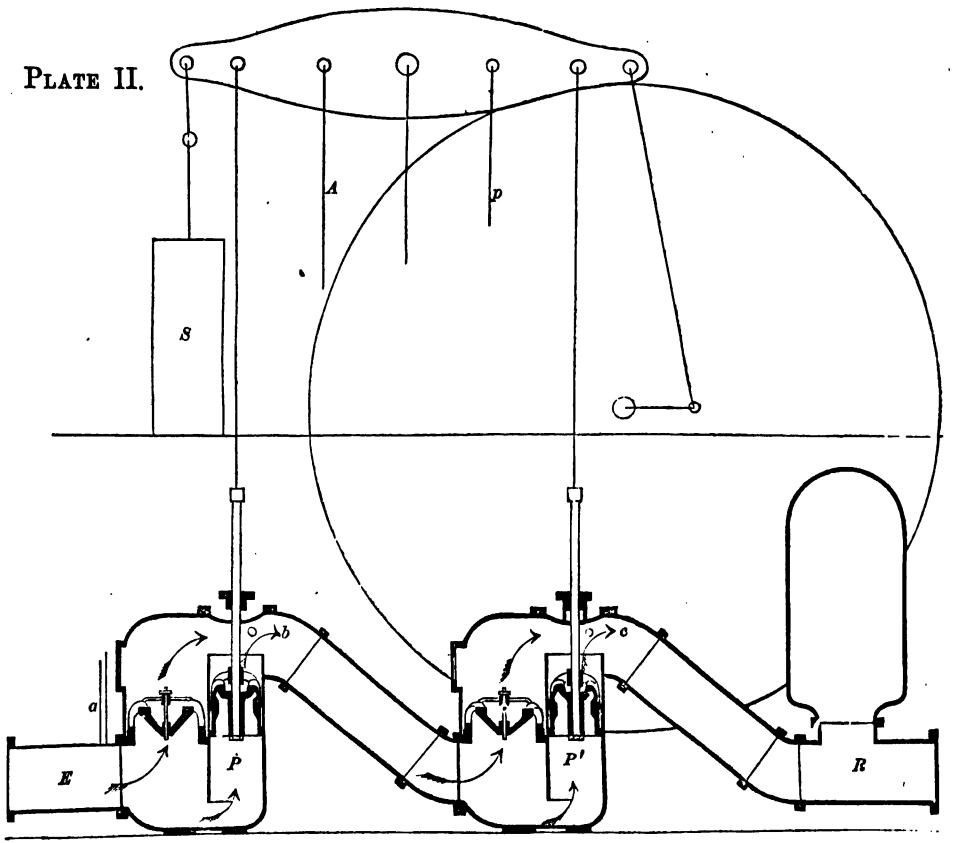
The results above deduced were entirely unexpected, but would be easily exceeded by the same pumps, were it attempted to obtain the highest duty and capacity during 16 hours only, by continuing at an uniform rate of speed and pressure. The position of so large pumps, upon a rising main, drawing their supply under a pressure of from 7 to 18 lbs. per square inch (varying with the draft in other parts of the city), is unusual; but, from the indicator cards, and general working of the engine, it appears that the pumps are as steady in their action as if they drew from a well, and much more economical in the consumption of coal, as the load is reduced by the amount of pressure in the main.

In some of the details there are a few trifling errors, which for the most part can be readily obviated in the after working. As a whole, I consider the machine satisfactory in its construction, results, and location.

Yours truly,
W. E. WORTHEN.

JUNE 3d, 1862.

PLATE II.



DESCRIPTION OF PROSPECT HILL PUMPING ENGINE.

PLATE II. represents a section in outline of the pumps, and an elevation of the pumping engine at Prospect Hill.

It will be observed that the engine is of the crank and fly-wheel variety, and in this respect is entirely different from the engine at Ridgewood. The steam cylinder *S* is fitted with slide valves, and a cut-off controlled by a governor constructed under Wright's patent. The speed during the experiments was varied by weights suspended to the governor rods. The pumps are constructed on the same general principles and mode of action as the pumps at Ridgewood. They are two pumps attached to opposite sides of the working beam; they have valves in their buckets, and in channels at the sides of the pump. The pumps are placed in a branch-main, and the water flows into and through the air pumps under a considerable head, variable with the draft upon the mains in other parts of the city. There are two air-chambers: one shown at *R* on the rising main, the other, and a somewhat larger one, is connected by a branch pipe with the induction pipe at *E*.

At *A* are the connections with the air pump. At *p* the connections of a small single acting plunger pump to supply the boiler feed, and return the injection water to the main.

By *P* is denoted the lower pump; by *P'* the upper; *a*, *b*, and *c* represent the apertures in connection with the indicator as explained in the report.

DIMENSIONS.

Steam Cylinder.

Length of stroke,	4 ft. 6 in.
Diameter of cylinder,	24 inches.
Diameter of piston rod,	3½ "

Pumps.

Length of stroke (average),	3.466 ft.
Diameter of barrels,	20¼ inches.
Diameter of piston rods,	3 "

Pump to return injection Water into the Main.

Length of stroke,	1.604 feet.
Diameter of plunger,	8 inches.

Fly Wheel.

Diameter	20 feet.
Length of crank,	27 inches.

Boiler—One, Drop Flue.

Length of shell,	18 feet.
Diameter of shell,	6 "
Length of fire grate,	5 "
Width of each fire grate during trial,	2 ft. 2½ in.
Number of upper flues,	4
Diameter of upper flues,	13 inches.
Length of upper flues,	11 feet.
Number of lower flues,	9
Diameter of lower flues,	7 of 9 in., 2 of 7 in.
Length of lower flues,	9 ft. 3 in.

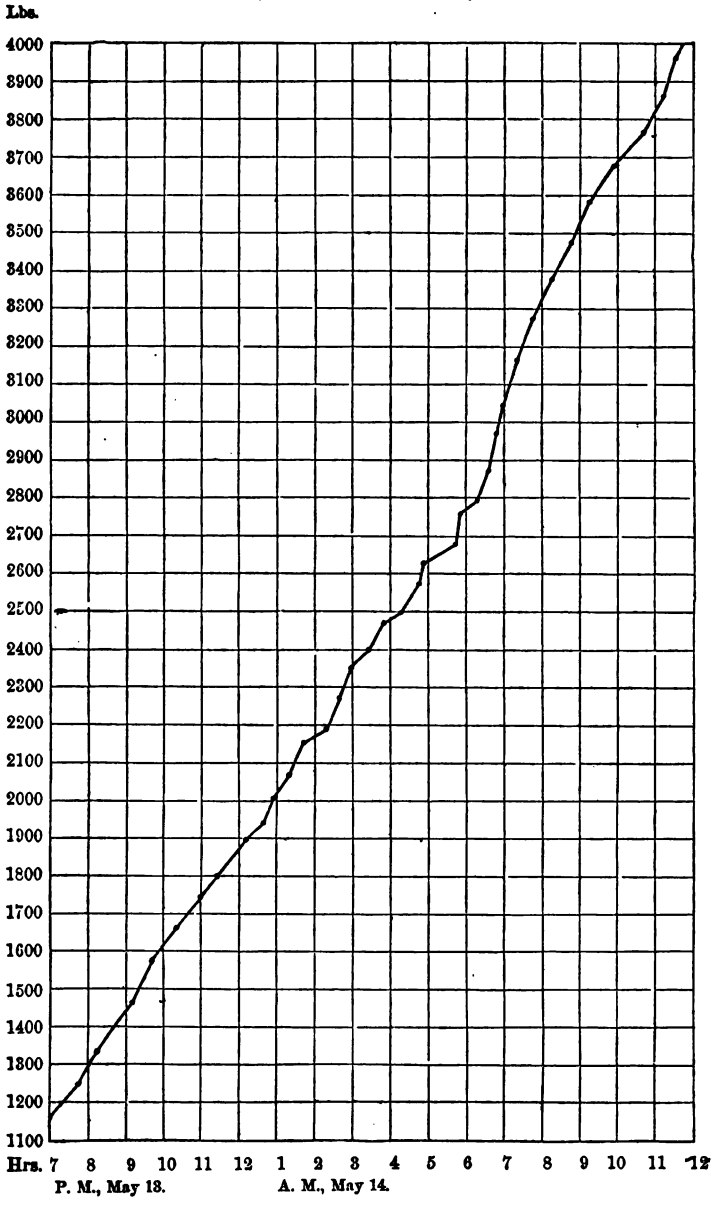
EXPLANATION OF COALING PROFILE.

The profile, page 36, of the coaling for 17 hours, will serve as an explanation of the form in which the register of coal consumed has been kept and plotted during the late experiments at Ridgewood and Prospect Hill. The hours selected have been taken rather than those at the commencement of the experiments, as profiles of steam and water pressures are given for the same period.

The firing was commenced on the morning of May 13, and the fires and water were got into the state in which it was determined to keep them as nearly as possible uniform. The coal was first noted at 0*h*. 14*m*. P. M., when 100 lbs. were thrown on one of the grates; at 1*h*. 2*m*. 100 lbs. on the other; at 1*h*. 55*m*. 60 lbs. on the first grate, and at 2*h*. 32*m*. 20 lbs. on the second. In this way the quantity of coal was taken every time any was put on, and on which grate thrown. The fire box was divided in two by a brick wall, to maintain a more even fire. The coal was weighed in lots of 100 lbs. each, and the amount at each firing was then estimated. At

6.56 P. M.	The total quantity fired was	1,155 lbs.
7.43 "	90 lbs.	1,245 "
8.12 "	100 "	1,345 "
9.03 "	Cleaned fire No. 2.	
9.10 "	120 lbs.	1,465 "
9.47 "	115 "	1,580 "
10.27 "	80 "	1,660 "
10.58 "	80 "	1,740 "
11.30 "	60 "	1,800 "
12.00 "	Cleaned fire No. 1.	

Coaling Profile.



12.06 P. M.	100 lbs.	1,900 lbs.
12.37 "	50 "	1,950 "
12.56 "	50 "	2,000 "
1.25 "	70 "	2,070 "
1.47 "	80 "	2,150 "
2.22 "	50 "	2,200 "
2.42 "	70 "	2,270 "
3.02 "	90 "	2,360 "

and so on; each of the firings is represented by dots on the profile, and the dots are connected by lines. In this way the firing is graphically represented, and the quantity consumed during a period of a few hours can be quite accurately determined.

The firemen were picked up in New York; had been employed on board of ocean steamers, and had never been inside of the building till the experiments were commenced. They were directed to keep the water as near as possible a certain level, and their fires always in one condition. The boiler pressure was varied from time to time to test the comparative economy of the engine under different pressures and speeds. The watch of the firemen was 12 hours on and 12 off.

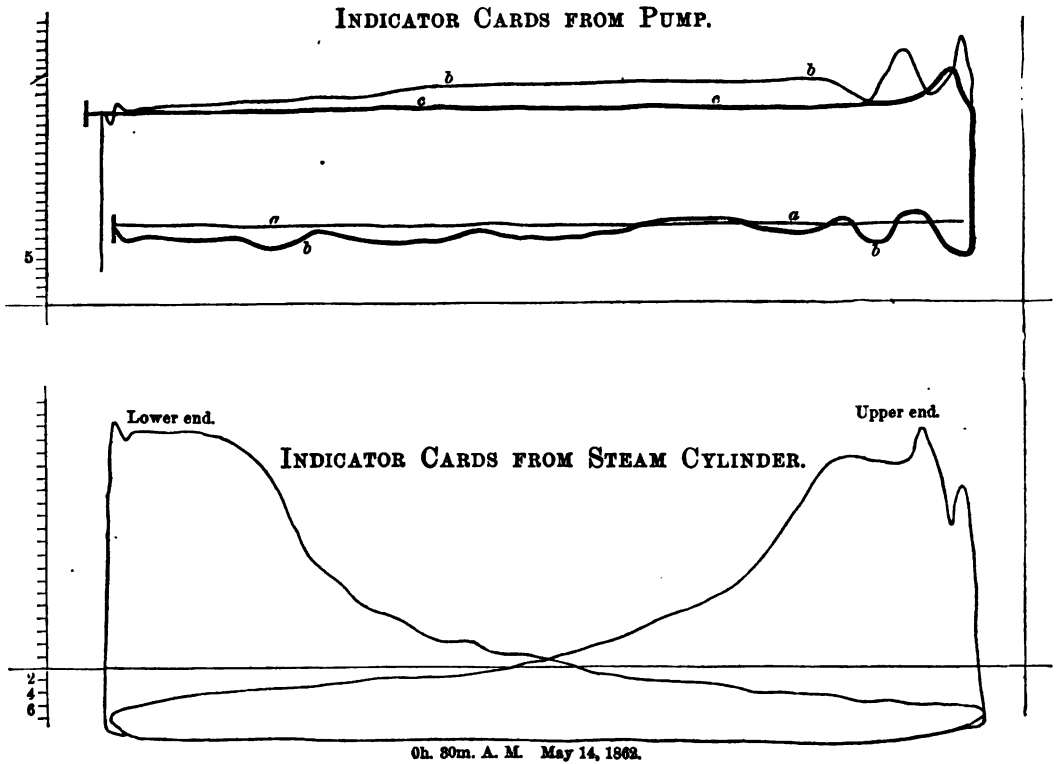
The coal used during the whole trial:

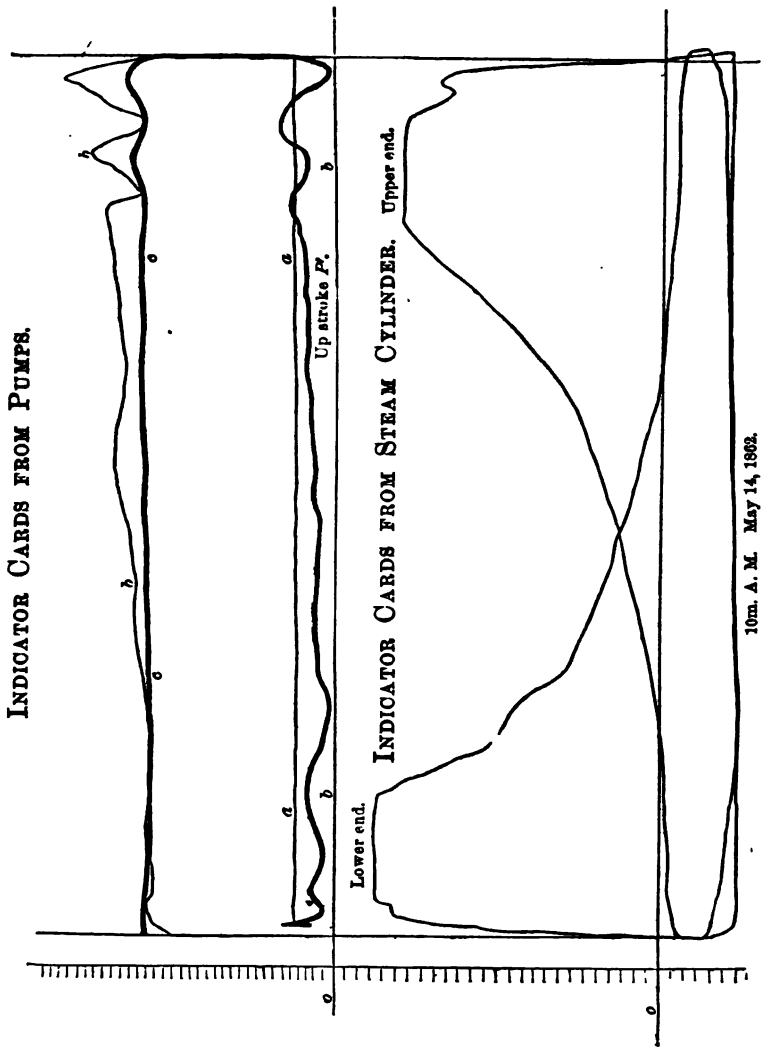
Of Delaware and Hudson Canal coal, . .	11,800 lbs.
Buck Mountain, ...	2,360 "
Total, ...	14,160
The total quantity of clinker, ...	645 lbs.
Small coal in ashes, ...	383 "

EXPLANATION OF INDICATOR CARDS.

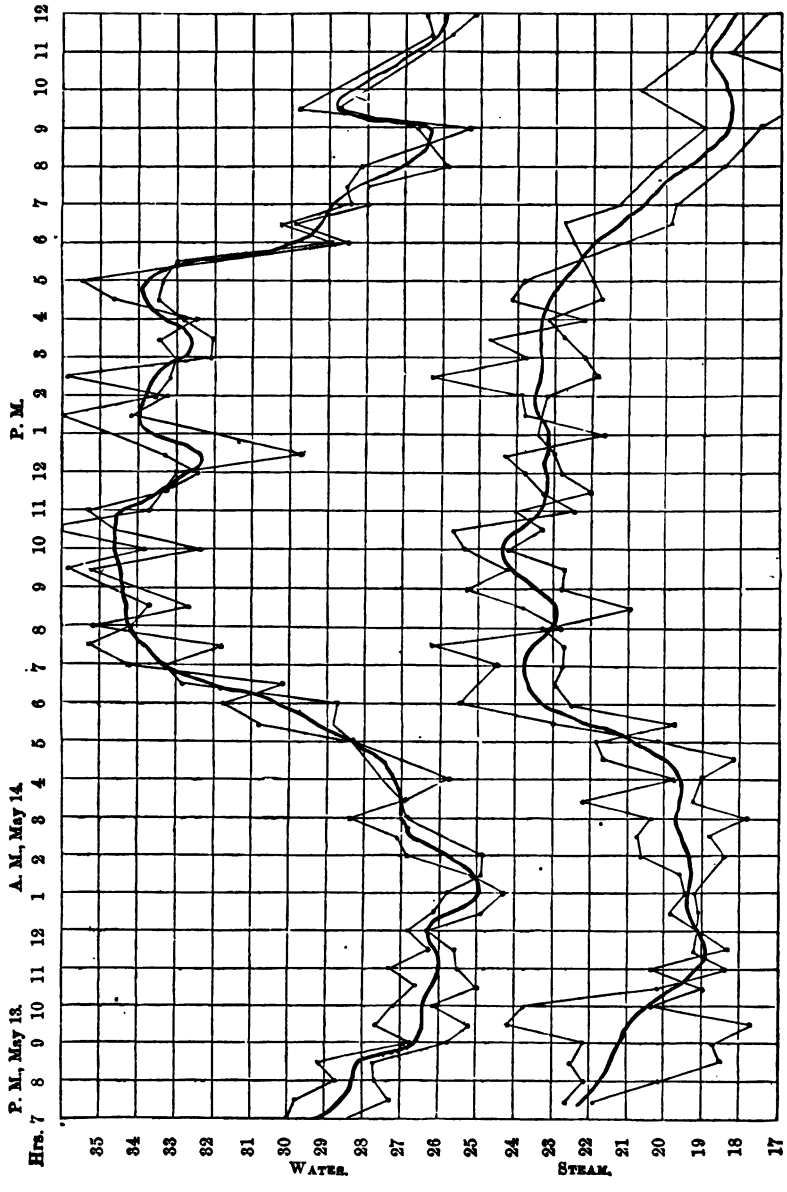
Indicator Cards are given, pp. 39, 40, taken from the steam cylinder and the pumps. The times at which they were taken correspond nearly to the times of maximum and minimum pressure ; in the main, at midnight the draft in the city is usually the least, and at 10 A. M. the most; and, conversely, the least load on the engine is about midnight, and the greatest from about 7 A. M. to 5 P. M., as will be seen by profile, p. 41.

It will be observed on the indicator cards, two lines are heavy, and two light ; the space included between the light lines represents the pressures on the lower pump *P* ; that between the heavy lines, the pressures on the upper pump *P'*. The lines marked "*a a*," are the pressures on the induction pipe *E*, directly below the lower pump ; and those "*c c*," the pressures on the rising main, directly above the upper pump ; these lines, during the strokes of either pump, vary inconsiderably. The upper lines "*b b*" represent the pressures on the lower pump, in its upward stroke, while "*c c*" represent the pressures with which the water is then forced in below the bucket. The lower lines "*b b*" are the pressures with which the water is forced into the upper pump *P*, whilst it makes its upward strokes, and "*c c*" are the pressures above its bucket at the same time.


INDICATOR CARDS FROM PUMP.
b
b
c
c
a
a
b
b
5
Lower end.
Upper end.
INDICATOR CARDS FROM STEAM CYLINDER.
2
4
6
0h. 30m. A. M. May 14, 1862.


Indicator Cards from Pumps.
Up stroke P'.
Indicator Cards from Steam Cylinder.
Upper end.
Lower end.
10m. A. M. May 14, 1862.

AVERAGE PRESSURE IN LBS. PER SQUARE INCH.



EXPLANATION OF PROFILE OF STEAM AND WATER PRESSURES.

Indicator Cards were taken every half hour during the experiments. The average pressures on steam cards were taken in the usual way, by an average of 10 ordinates; those of the pumps by the same number of ordinates, and as explained in Report and Explanation of indicator cards.

To average the pressures at each end of the cylinders, and on each of the pumps, it was thought the more correct to do this graphically, and when plotted on the same profile, they afford a comparison of the variations of power exerted, and work done.

Table of average pressures on steam cylinders and pumps.

		PUMPS.		STEAM CYLINDER.	
		LOWER.	UPPER.	LOWER END.	UPPER END.
May 13, P. M.	7.00	30.	28.5		
	7.30	29.85	27.3	22.6	21.9
	8.00	28.70	27.75	22.05	20.25
	8.30	29.20	27.70	22.55	18.55
	9.00	26.6	25.95	22.55	18.70
	9.30	27.7	25.25	24.3	17.6
	10.00	27.25	26.15	23.8	20.4
	10.30	26.6	25.	20.1	18.7
	11.00	27.2	25.5	18.25	20.35
	11.30	26.4	25.5	19.3	18.35
	12.00	27.	26.2		
May 14, A. M.	12.30	26.05	24.95	19.1	19.9
	1.00	25.85	24.3	19.2	19.4

By comparison of the above table with the profile, it will be seen how the pressures are plotted. The heavy

lines represent the average between the two pressures of cylinder and of pumps.

By the inspection of this profile, one may observe how the work required varies with the draft on the main during different parts of the day, and how the average pressure on the cylinder, or power exerted, varies relatively to the work required.

It will also be readily understood, that by plotting a profile of coal consumed, and averaging the pressures of steam and of water, as on Profile p. 41, a much more accurate estimate may be formed of the duty of an engine, either at the steam or water end, than in the usual way, and over a much shorter period of time. The assistants in charge of the various departments continue their charge, not knowing what time or times may be selected for the test; vigilance is insured, and negligence or carelessness will leave its marks on the profiles.

Table of Results of Experiments made on Prospect Hill Pumping Engine, May 13th, 14th, 15th, 16th, and 17th, 1862.

DATE, 1862.		Number of Revolutions during the Hour.	AVERAGE.							Gross Amount of Coal consumed during the Hour.	REMARKS.
			Mean Steam Pressure per square inch in Steam Cylinder.	Mean Water Load per sq. inch in Pumps.	Boiler Pressure per square inch.	Vacuum in Condenser.	STEAM CYLINDER.				
							Initial Pressure.	Cut off. Full Stroke, 1.00.	Final Pressure below 0.		
Day.	Hour.	1.	2.	3.	4.	5.	6.	7.	8.	9.	
			Lbs.	Lbs.	Lbs.	In.	Lbs.		Lbs.	Lbs.	
May 13	8 P. M.	1,478	22.3	28.7	47.6	27.3	42.	.15	3.5	140	7h Ryan commenced firing.
	9 "	1,487	21.7	27.8	47.3	27.	39.	.15	5.	145	9h 8' cleaned No. 2 fire.
	10 "	1,482	21.2	26.8	45.7	27.	40.	.18	5.5	160	
	11 "	1,494	20.4	26.25	45.0	27.4	39.5	.14	6.	140	
	12 "	1,523	19.6	26.0	46.1	27.2	37.	.15	6.5	140	12h 8' cleaned No. 1 fire.
" 14	1 A. M.	1,578	19.15	25.5	45.1	27.2	35.	.15	6.	125	
	2 "	1,600	19.15	25.25	44.3	27.5	34.	.15	6.	160	
	3 "	1,688	19.25	26.6	46.5	27.5	38.	.16	6.	168	
	4 "	1,686	19.5	27.3	48.	27.5	38.5	.15	5.5	121	
	5 "	1,720	20.1	27.8	48.5	27.5	39.	.16	5.5	160	
	6 "	1,775	21.9	29.3	47.	27.5	38.2	.20	4.	130	6h 20' Kenny commenced firing.
	7 "	1,771	23.75	32.1	47.5	27.5	39.	.20	4.5	285	
	8 "	1,680	24.5	33.9	45.	27.5	35.5	.17	3.5	260	
	9 "	1,679	23.9	34.75	49.7	27.5	41.	.19	3.5	210	9h 18' cleaned No. 1 fire.
	10 "	1,675	24.1	35.15	45.8	27.5	41.	.18	4.5	170	
	11 "	1,670	24.1	34.9	45.6	27.5	42.5	.18	3.5	150	
	12 "	1,669	23.4	33.5	51.1	27.5	42.	.18	4.	200	
	1 P. M.	1,645	23.35	33.35	49.	27.5	42.	.18	4.	200	
	2 "	1,668	23.45	33.75	48.5	27.5	41.	.19	3.5	190	2h 20' cleaned No. 2 fire.
	3 "	1,668	23.6	33.65	44.1	27.4	36.	.19	3.	220	
	4 "	1,664	23.55	33.25	48 0	27.5	41.5	.15	3.5	218	
	5 "	1,681	23.15	33.7	46.2	27.4	37.5	.18	3.5	185	
	6 "	1,514	23 3	32.3	46 8	27.6	39.5	.16	4.5	120	6h 25' Ryan fires.
	7 "	1,289	21.4	29.1	49.7	27.7	39.2	.15	4.5	125	
	8 "	1,288	20.1	27.55	48.0	27.2	38.5	.14	5.5	105	
	9 "	1,285	19.0	26.5	48.0	27.2	37 5	.15	6.	110	
	10 "	1,286	18.5	28.8	48 5	27.6	37.	.14	6.5	140	10h cleaned No. 1 fire.
	11 "	1,293	18.5	27.8	48.0	27.7	36.5	.15	6.	150	
	12 "	1,299	18 4	25.05	46.5	27.7	36.5	.15	6.	120	
15	1 A. M.	1,279	18.0	24.45	46.75	27.7	35.5	.15	6.	120	
	2 "	1,280	17.55	24.45	47.5	27.7	34.5	.18	6.	180	2h 5' cleaned No. 2 fire.
	3 "	1,286	17.2	23.9	45.5	27.5	34.5	.19	6.	125	
	4 "	1,281	16.95	24.8	45.5	27.2	34.5	.18	6 5	116	
	5 "	1,279	17.7	25.8	45.2	27.5	34.5	.14	6.5	140	
	6 "	1,286	19.3	28.6	46.5	27.7	38.	.17	5.5	110	6h 21' Kenny fires.
	7 "	1,276	21.55	31.7	45.5	27.7	38.	.20	4 5	158	
	8 "	1,258	22.65	33 55	37.5	27.7	32.	.25	4.5	161	
	9 "	1,255	22.35	33.5	33 5	27.9	29.5	.25	4.	190	9h 25' cleaned No. 1 fire.
	10 "	1,254	21.85	32.1	34.7	27.9	31.5	.24	3.5	190	
	11 "	1,256	21.3	30.5	34.	27.9	30.5	.23	3.5	169	
	12 "	1,258	21.1	30.0	34.5	28.	31.	.23	3 5	140	12h 32' cleaned No. 2 fire.
	1 P. M.	1,231	20 95	30.0	35.5	28.	31.5	.20	4.	150	
	2 "	1,266	20 85	30.8	35.0	28.	33.	.24	4.5	110	
	3 "	1,255	20 8	30.5	35.5	28.	30.	.22	5.	184	
	4 "	1,260	20.15	29.7	36.	28.	31.5	.21	5.	110	
	5 "	1,256	20.25	29.55	33.	28.	29.	.23	4.	115	
	6 "	1,264	20 75	29.9	31.5	28.	28.5	.26	4.	119	6h 40' Ryan fires.

DATE, 1862.		Number of Revolutions during the Hour.	AVERAGE.							Gross Amount of Coal consumed during the Hour.	REMARKS.
			Mean Steam Pressure per square inch in Steam Cyl. under.	Mean Water Load per sq. inch in Pumps.	Boiler Pressure per square inch.	Vacuum in Condenser.	STEAM CYLINDER.				
							Initial Pressure.	Cut off. Full Stroke, 1.00.	Final Pressure below 0.		
Day.	Hour.	1.	2.	3.	4.	5.	6.	7.	8.	9.	
			Lbs.	Lbs.	Lbs.	In.	Lbs.		Lbs	Lbs.	
May 15	7 P. M.	1,233	20.75	30.65	33.5	27.7	29.	.26	3.5	100	
	8 "	1,277	19.9	27.6	32.	27.5	25.5	.23	3.5	96	
	9 "	1,260	18.6	26.8	31.5	27.5	25.5	.20	5.	90	9h 38' cleaned No. 2 fire.
	10 "	1,264	17.95	26.65	31.5	27.5	24.5	.19	5.5	120	
	11 "	1,267	17.8	26.4	31.5	27.5	26.5	.18	5.5	195	11h 18' cleaned No. 1 fire.
	12 "	1,266	17.9	25.95	32.	27.5	25.5	.22	5.5	144	
" 16	1 A. M.	1,252	17.7	25.5	27.	27.6	21.	.27	5.	141	
	2 "	1,244	17.85	25.35	21.5	27.7	17.	.30	4.5	130	
	3 "	1,241	17.85	25.35	21.	27.6	17.	.33	3.5	100	
	4 "	1,238	17.5	25.35	21.	27.6	17.5	.28	3.5	140	
	5 "	1,239	17.8	25.9	20.5	27.7	17.	.30	4.	130	6h 30' Kenny fires.
	6 "	1,238	18.3	27.8	19.5	27.6	15.5	.42	2.5	160	
	7 "	1,229	19.15	30.4	20.	27.4	16.5	.38	1.	164	
	8 "	1,198	20.5	31.95	21.	26.9	20.	.37	1.	125	8h 55' cleaned No. 1 fire.
	9 "	1,204	21.15	32.3	20.	26.5	19.5	.43	1.	180	
	10 "	1,208	20.7	31.9	20.5	26.5	18.5	.38	1.	150	10h 14' cleaned No. 2 fire.
	11 "	1,175	20.4	31.15	20.	27.	19.	.25	2.5	204	
	12 "	1,262	21.3	31.15	23.	27.5	23.	.31	2.5	205	12h 10' Ridgewood fireman com'd firing.
	1 P. M.	1,490	22.5	33.3	38.	27.5	33.	.18	3.	155	
	2 "	1,480	22.5	34.15	49.	27.7	48.	.19	3.5	120	
	3 "	1,482	21.7	34.1	48.5	28.2	40.5	.19	3.5	190	3h 56' cleaned No. 1 fire.
	4 "	1,482	21.5	34.61	48.5	28.2	41.	.20	3.5	165	
	5 "	1,481	21.3	35.75	48.5	27.9	40.	.18	4.5	190	
	6 "	1,405	21.4	32.15	49.	28.	40.	.19	4.5	195	6h 40' Ryan fires.
	7 "	1,408	21.85	32.35	48.	27.9	40.	.20	4.	180	
	8 "	1,406	21.45	31.7	49.	27.5	40.5	.18	4.	160	
	9 "	1,404	21.5	30.0	50.	27.5	41.	.17	4.5	170	
	10 "	1,408	20.7	28.75	49.5	27.5	40.	.17	4.5	145	
	11 "	1,396	19.4	27.95	49.	27.5	38.	.15	5.5	165	11h 50' cleaned No. 2 fire.
	12 "	1,356	18.7	27.15	47.	27.6	37.	.16	5.5	180	
" 17	1 A. M.	1,267	18.3	26.7	47.5	27 6	34.5	.05	4.5	120	
	2 "	1,313	18.6	26.75	49.5	27.5	32.5	.07	4.5	120	
	3 "	1,308	19.15	26.95	49.	27.5	31.	.12	4.5	130	
	4 "	1,383	20.0	27.15	49.5	27.5	35.	.18	4.5	120	
	5 "	1,385	20.75	28.5	48.5	27.5	39.5	.18	4.5	120	5h 30' cleaned No. 1 fire.
	6 "	1,382	20 95	32.8	47.5	27.1	39.5	.20	3.5	144	6h 30' Ridgewood fireman com'd firing.
	7 "	1,376	23.3	35.5	48.	27.	42.25	.21	2.5	166	
	8 "	1,376	24.3	36.7	47.5	27.	42.5	.21	2 5	150	
	9 "	1,375	24.0	37.5	47.	27.	41.	.22	2 5	150	

NOTE.

	Lbs.
Used Delaware and Hudson Coal, from commencement to 10 A. M., May 16th	10,500
At 10.5 A. M., May 16th, used Buck Mountain Coal	100
Used Delaware and Hudson Canal Coal, from 10.35 A. M., Friday, to 31 min. P. M., Friday, 16th	500
Used Buck Mountain Coal, from 1.23 P. M., Friday, to 11 49 P. M., Friday	1,900
Used Delaware and Hudson Canal Coal, from 12.45 P. M., Friday, to 6.10 A. M., Saturday	600
Used Buck Mountain Coal from 6.37 A. M., Saturday, 17th, to end of trial	360
Total Coal used	14.160
Amount of Coal used in Furnace No. 1	7.380
" " " No. 2	6,880
Clinkers during trial	645
Ashes during trial	959
40 per cent. of which was found to be small coal	383

EXPLANATION OF TABLE.

COLUMN 1 contains the number of revolutions during the hour, found by subtracting from the number, as shown by the counter at the hour on the line, the number at the previous hour. The number of revolutions from the commencement of the experiments, 12 M. to 7 P. M., was 11,119.

Column 2 contains the mean pressure of steam in the cylinder during the hour, and was found, first, by averaging the pressure on the cards, as taken by the indicator every half hour, then plotting these pressures on a profile, and taking the mean, as shown at page 41.

Column 3 contains the mean pressure of water load in pumps, taken from the indicator cards, and profile plotting, like that for the steam pressure, column 2.

Column 4 contains the average boiler pressure found by observations of the steam pressure gauge in the engine room.

Column 5 contains an average of the vacuum in the condenser, taken from observations of the vacuum gauge in the engine room.

Column 6 contains the average pressures in the steam cylinder at commencement of stroke, taken from the indicator cards, plotted on profile, as at page 41.

Column 7 shows the average point at which the steam was cut off in the cylinder, taken from the indicator cards, and also plotted in profile.

Column 8 contains the average pressure in cylinder at end of stroke, determined like that of the initial pressures, column 6.

Column 9 contains the amount of coal consumed during the hour, no deduction being made for small coal or cinders in the ashes. The amounts are determined from the profile, as in page 36. Coal used from 12 M. to 7 P. M., May 15, 1,265 lbs.

EVAPORATION.

The evaporation—as determined from the volumes of steam in the cylinder at the end of the stroke, and referred by Pambour's formula to water at 32° Fahrenheit, and then by the English Admiralty formula to the standard of 100° Fahrenheit—was found to be 7.565 lbs. of water per lb. of coal.

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